Absorption enhancement in organic solar cells by metallic nanoparticles

Honghui Shen

Supervisor(s): Peter Bienstman, Bjorn Maes

I. INTRODUCTION

As the price of energy continues to rise, people are looking to renewable energy for cheaper sources of power. Solar energy is one of the promising renewable and clean power sources. However, the conventional silicon-based solar cells have not been able to compete economically with fossil fuels. Now, organic solar cells (OSCs) may be one of the most promising technologies in search of sustainable, renewable energy sources. OSCs will be a cheap and potentially simple alternative energy. Other attractive properties of OSCs are good mechanical flexibility, feather-weight, easy to produce and so on.

However, OSCs are still in the research phase and have a very low efficiency, up to 5-6% [1], much smaller than the commercial silicon-based solar cells. Fortunately, with the help of some noble metal nanoparticles (MNPs), such as silver or gold, the efficiency of OSCs can be improved. This is due to the electrons in MNPs, which oscillate together with the frequency of the incident sunlight. As a result, the electric field near MNPs and the scattered field from MNPs can be enhanced. Both the near field enhancement and enhanced scattering can be used to increase the absorption of the sunlight and the efficiency of the cells.

Recently, some experimental results [2, 3] show that with the MNPs, the efficiency of OSCs can have a significant improvement. Here, in this paper, based on numerical calculations of 2D model of OSCs, we show the possibility of absorption enhancement in OSCs by embedded MNPs into active layer.

II. STRUCTURE OF OSCS

Figure 1 shows the schematic picture of OSCs under investigations, starting with the cathode, then the active layer followed by the anode. The anode is a highly conductive polymer, poly (3, 4-ethylenedioxythiophe-ne):poly (styrenesulfonate) (PEDOT: PSS) which is a polymer with good thermal and chemical stability and good flexibility. For the active layer, the commonly used polymer, poly(3-exylthiophene):(6,6)-phenyl-C61-butyric-acid-methyl ester (P3HT:PCBM) with 1:1 weight ratio is used. The material of the cathode is aluminum and the MNPs are silver. The thickness of the active layer is 33nm. The diameter of the MNPs is fixed at 10nm.

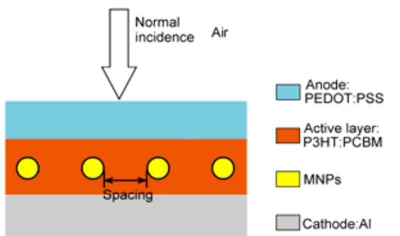

Figure 1. Schematic picture of OSCs with MNPs

We use a 2D model, which means the MNPs are a periodic array of cylindrical nanowires, which are embedded in the middle of the active layer. Simulations were

H. Shen is with the Department of Information Technology, Ghent University (UGent), Gent, Belgium. E-mail: Honghui.Shen@intec.ugent.be.

performed using the commercial fully vectorial COMSOL software package. Light with electric field normal to the nanowires is normally incident from the air into the solar cell (see Figure 1), passing the PEDOT:PSS, the active layer and then reaching the cathode. Some light is absorbed in the anode, the active layer and the cathode, and the rest of it is reflected away from the solar cell.

III. Results

Figure 2 shows the spacing (distance between neighboring MNPs, see Figure 1) dependence of absorption enhancement. Absorption enhancement is defined as a ratio of absorption with MNPs to that without MNPs. This figure shows that there exists an optimum spacing of 8nm maximizing the absorption enhance-ment with a factor of around 1.48.

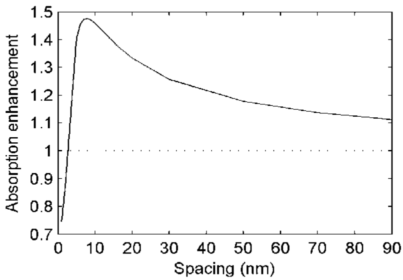

Figure 2. Absorption enhancement with MNPs versus spacing.

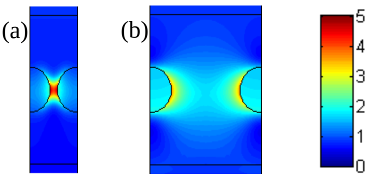

Figure 3. The representative E field enhancement with different spacing, (a) 2nm and (b) 16nm.

As the spacing increases, the electric field enhancement near MNPs gets smaller However, the field enhancement begins to spread out. This is due to the decoupling between neighboring MNPs as illustrated by Figure 3. When MNPs are far away from each other, the structure converges to the case with no MNPs (no absorption enhancement). As a consequence of these competing effects, there exists an optimum spacing as shown in Figure 2. From figure 3, we can also see that the enhanced field is mainly localized in the spacing between MNPs, which implies that the absorption enhancement is mainly due to the near field enhancement, not the enhanced scattering. This enhancement mechanism is confirmed by further investigations [4].

IV. Conclusion

Based on a 2D model, we have shown the absorption enhancement by incorporating MNPs into active layer. We observed enhancement with a maximum factor of 1.48. The enhancement mechanism is due to the near field enhancement.

Acknowledgements

The authors would like to acknowledge support from the IWT (Institute for the Promotion of Innovation by Science and Technology in Flanders) via the SBO-project 060843 "Polyspec", the Foundation-Flanders (FWO), and the Interuniversity Attraction Poles program of the Belgian Science Policy Office, under grant IAP P6-10 "photonics@be".

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